

THAT WHICH IS CLAIMED:

1. A method of estimating reserve life for a battery, the method comprising:

adaptively modifying a model of battery reserve life that a function of a SOH indicator responsive to intermittent capacity tests of the battery;

5 monitoring the SOH indicator for the battery to generate SOH indicator values; and

generating estimates of reserve life from the generated SOH indicator values according to the adaptively modified model of battery reserve life.

10 2. A method according to Claim 1, wherein adaptively modifying a model of battery reserve life comprises adaptively modifying the model of battery reserve life responsive to battery reserve life estimates that are based on the capacity tests.

15 3. A method according to Claim 1, wherein adaptively modifying comprises performing a capacity test responsive to detection of a change in reserve life as estimated by the model of battery reserve life, and modifying the model of battery reserve life responsive to the capacity test.

20 4. A method according to Claim 1, wherein adaptively modifying comprises performing a capacity test upon lapse of predetermined time interval, and modifying the reserve life mode responsive to the capacity test.

25 5. A method according to Claim 1, wherein the battery reserve life model expresses reserve life as a function of at least one of a float voltage, a float current, a temperature, a charge/discharge cycling, an impedance, a conductance, a resistance, and a coup de fouet parameter.

30 6. A method according to Claim 1, comprising initializing the model of battery reserve life based on rated reserve life and/or a training test.

7. A method according to Claim 1:
wherein the adaptively modified model of battery reserve life comprises a first adaptively modified model of battery reserve life;
wherein monitoring the SOH indicator to generate SOH indicator values
5 comprises monitoring a first SOH indicator during a first time interval to generate first SOH indicator values for the first time interval;
wherein generating estimates of reserve life from the generated SOH indicator values according to the adaptively modified model of battery reserve life comprises generating estimates of reserve life for the first time interval from the generated first
10 SOH indicator values for the first time interval; and
wherein the method further comprises:
monitoring a second SOH indicator to generate second SOH indicator values for a second time interval; and
generating estimates of reserve life from the generated second SOH
15 indicator values according to a second model of battery reserve life.

8. A method according to Claim 7, wherein generating estimates of reserve life from the generated second SOH indicator values comprises adaptively modifying the second model of battery reserve life at a reduced rate with respect to
20 the first model of battery reserve life.

9. A method of estimating reserve life of a battery, the method comprising:
generating respective first state of health (SOH) indicator values for respective
25 elapsed times for the battery;
generating respective first estimates of reserve life from the first SOH indicator values according to a battery reserve life model;
performing a capacity test of the battery to generate a second estimate of reserve life responsive to one of the first estimates of reserve life indicating a change
30 in reserve life exceeding a predetermined threshold;
modifying the battery reserve life model based on the second estimate of reserve life;
generating a second SOH indicator value; and

generating a third estimate of reserve life from the second SOH indicator value according to the modified battery reserve life model.

10. A method according to Claim 9, wherein modifying the battery reserve
5 life model based on the second estimate of reserve life comprises modifying the battery reserve life model based on a comparison of the first and second estimates of reserve life.

11. A method according to Claim 10, wherein modifying the battery
10 reserve life model based on a comparison of the first and second estimates of reserve life comprises modifying the battery reserve life model if the second estimate of reserve life indicates a diminished reserve life of the battery in comparison to the first estimate of reserve life.

12. A method according to Claim 10, wherein modifying the battery
15 reserve life model based on a comparison of the first and second estimates of reserve life comprises generating a solution for a parameter of the battery reserve life model from the battery model and the second estimate of reserve life to generate a modified parameter for the battery model.

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13. A method according to Claim 10, wherein monitoring a state of health
(SOH) indicator for the battery to generate a series of first SOH indicator values
comprises monitoring at least one of a float voltage, a float current, a temperature, a
charge/discharge cycling, an impedance, a conductance, a resistance, and a coup de
25 fouet parameter to generate the SOH indicator values.

14. A method according to Claim 13, wherein the battery reserve life
model expresses battery reserve life as a function of at least one of a float voltage, a
float current, a temperature, a charge/discharge cycling, an impedance, a conductance,
30 a resistance, and a coup de fouet parameter.

15. A method according to Claim 14, wherein the battery reserve life
model comprises a battery reserve life model represented by the equation:

$$L_R(t_x) = f(T) = \beta \cdot \left[\frac{L_n - \sum_{i=1}^x (t_i - t_{i-1}) \cdot 2^{\frac{(T_i - T_n)}{\alpha}}}{2^{\frac{(T_x - T_n)}{\alpha}}} \right],$$

wherein $L_R(t_x)$ is the estimated reserve life at time t_x , T_x is the present temperature at time t_x , L_n is a manufacturer's designed life at a nominal temperature T_n , α is a
 5 parameter reflecting a change in temperature that results in the life of the battery changing by a factor of two, and β is a scaling parameter.

16. A method according to Claim 9, wherein performing the capacity test responsive to one of the first estimates of reserve life indicating a change in battery
 10 reserve life exceeding a predetermined threshold comprises performing the capacity test responsive to one of the first estimates of reserve life indicating a change in reserve life with respect to a rated life of the battery that exceeds a predetermined threshold.

15 17. A method according to Claim 9:
 wherein performing the capacity test is preceded by performing a training test to generate an initial estimate of reserve life; and
 wherein performing a capacity test comprises performing the capacity test responsive to one of the first estimates of reserve life indicating a change in reserve
 20 life with respect to the initial estimate of reserve life that exceeds a predetermined threshold.

18. A method according to Claim 17, wherein performing a training test comprises:
 25 shallow discharging the battery to generate a coup de fouet parameter value;
 and
 generating the initial estimate of reserve life from the generated coup de fouet parameter value.

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19. A method according to Claim 18:
wherein generating respective first SOH indicator values comprises generating respective first coup de fouet parameter values for respective elapsed times;
wherein generating respective first estimates of reserve life from the first SOH indicator values according to a battery reserve life model comprises generating
5 respective first estimates of reserve life from respective ones of the first coup de fouet parameter values;
wherein generating a second SOH indicator value comprises generating a second coup de fouet parameter value; and
10 wherein generating a third estimate of reserve life from the second SOH indicator value according to the modified battery reserve life model comprises producing the third estimate of reserve life from the generated second coup de fouet parameter value.
- 15 20. A method according to Claim 10, further comprising presenting a reserve life indication to a user based on at least one of the first and third estimates of reserve life.
21. A method according to Claim 20, wherein presenting a reserve life
20 indication comprises at least one of displaying a reserve life indication and communicating a reserve life indication.
22. A method according to Claim 9, wherein the battery comprises a valve-regulated lead-acid (VRLA) battery.
- 25 23. An apparatus for estimating battery reserve life, the apparatus comprising:
means for adaptively modifying a model of battery reserve life that a function
of a SOH indicator responsive to intermittent capacity tests of the battery;
30 means for monitoring the SOH indicator for the battery to generate SOH indicator values; and
means for generating estimates of reserve life from the generated SOH indicator values according to the adaptively modified model of battery reserve life.

24. An apparatus according to Claim 23, wherein the means for adaptively modifying comprises means for adaptively modifying the model of battery reserve life that a function of a SOH indicator responsive to reserve life estimates generated by the intermittent capacity tests.

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25. An apparatus according to Claim 23, wherein the means for adaptively modifying comprises means for performing a capacity test responsive to detection of a change in reserve life as estimated by the model of battery reserve life and for modifying the model of battery reserve life responsive to the capacity test.

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26. An apparatus according to Claim 23, wherein the means for adaptively modifying comprises means for performing a capacity test upon lapse of predetermined time interval and for modifying the reserve life mode responsive to the capacity test.

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27. An apparatus according to Claim 23, wherein the battery reserve life model expresses reserve life as a function of at least one of a float voltage, a float current, a temperature, a charge/discharge cycling, an impedance, a conductance, a resistance, and a coup de fouet parameter.

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28. An apparatus according to Claim 23:

wherein the adaptively modified model of battery reserve life comprises a first adaptively modified model of battery reserve life;

25 wherein the means for monitoring the SOH indicator to generate SOH indicator values comprises means for monitoring a first SOH indicator during a first time interval to generate first SOH indicator values for the first time interval;

30 wherein the means for generating estimates of reserve life from the generated SOH indicator values according to the adaptively modified model of battery reserve life comprises means for generating estimates of reserve life for the first time interval from the generated first SOH indicator values for the first time interval; and

wherein the means for monitoring the SOH indicator to generate SOH indicator values further comprises means for monitoring a second SOH indicator to generate second SOH indicator values for a second time interval; and

wherein the means for generating estimates of reserve life from the generated SOH indicator values according to the adaptively modified model of battery reserve life further comprises means for generating estimates of reserve life from the generated second SOH indicator values according to a second model of battery
5 reserve life.

29. An apparatus according to Claim 28, wherein the means for generating estimates of reserve life from the generated second SOH indicator values comprises means for adaptively modifying the second model of battery reserve life at a reduced
10 rate with respect to the first model of battery reserve life.

30. An apparatus, comprising:
an adaptive battery reserve life estimator configured to adaptively modify a model of battery reserve life for a battery that a function of a SOH indicator
15 responsive to intermittent capacity tests of the battery, to monitoring the SOH indicator for the battery to generate SOH indicator values, and to generate estimates of reserve life from the generated SOH indicator values according to the adaptively modified model of battery reserve life.

20 31. A computer program product for estimating reserve life of a battery, the computer program product comprising computer program code embodied in a computer readable medium, the computer program code comprising:
first program code configured to adaptively modify a model of battery reserve life that is a function of a SOH indicator responsive to intermittent capacity tests of
25 the battery;
second program code configured to monitor the SOH indicator for the battery to generate SOH indicator values; and
third program code configured to generate estimates of reserve life from the generated SOH indicator values according to the adaptively modified model of battery
30 reserve life.

32. A computer program product according to Claim 31, wherein the first program code is configured to adaptively modify the model of battery reserve life responsive to reserve life estimates generated by the intermittent capacity tests.

33. A computer program product according to Claim 31, wherein the first program code is configured to cause a capacity test responsive to detection of a change in reserve life as estimated by the model of battery reserve life and to modify
5 the model of battery reserve life responsive to the capacity test.

34. A computer program product according to Claim 31, wherein the first program code is configured to cause a capacity test upon lapse of predetermined time interval and to modify the reserve life mode responsive to the capacity test.
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35. A computer program product according to Claim 31, wherein the battery reserve life model expresses reserve life as a function of at least one of a float voltage, a float current, a temperature, a charge/discharge cycling, an impedance, a conductance, a resistance, and a coup de fouet parameter.